charles river analytics

Charles River Analytics Inc.
625 Mount Auburn St.
Cambridge, MA 02138
www.cra.com

p: 617.491.3474
f: 617.868.0780

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Reference: Government Contract No. N00014-09-C-0050, "Enhancing Simulation-based Training Adversary Tactics via Evolution (ESTATE)"
Charles River Analytics Contract No. C08098

Subject: Contractor's Status Report: Quarterly Status Report #8
Reporting Dates: 9/15/2010 – 12/15/2010

Dear Dr. Hawkins,

The following is the Contractor's Quarterly Status Report for the subject contract for the indicated period. During this reporting period we have concentrated on Task 6: Simulation-based Training System Integration and Task 8: Transition

1. Summary of Progress

1.1 ONR Program Review

During the current reporting period, we presented ESTATE at the two-day ONR 341 Program Review for Harold Hawkins on 4-5 October 2010. The review included program presentations from ONR-funded performers on human cognitive performance predictors such as neural plasticity, working memory, and adaptive performance as well as population modeling and computational approaches for 21st Century Naval Operations. Interactions with the review participants helped us to consider future directions for the ESTATE adaptive training approach as applied to cognitive performance factors.

At the review, we met Dr. Kendy Vierling, a senior analyst at the Human Performance, Training, and Education MAGTF Training Simulations Division of the US Marine Corps. We are corresponding with Dr. Vierling, who has been helpful in finding opportunities for ESTATE in the USMC Training Systems Division. We are currently pursuing possibilities for adaptive cultural training in virtual environments.

1.2 ESTATE with PROMPTER

As previously reported at the annual ONR Program Review, we are now in the process of selecting and implementing challenge domains to evaluate the ESTATE approach. We considered constructing toy domains that match the abstract challenge games previously used to simulate ESTATE performance, such as a maze type game to simulate a challenge tree. These toy domains are advantageous in that they may be quickly implemented and evaluated. However,

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14. ABSTRACT
During the current reporting period, we presented ESTATE at the two-day ONR 341 Program Review for Harold Hawkins on 4-5 October 2010. The review included program presentations from ONR-funded performers on human cognitive performance predictors such as neural plasticity, working memory, and adaptive performance as well as population modeling and computational approaches for 21st Century Naval Operations. Interactions with the review participants helped us to consider future directions for the ESTATE adaptive training approach as applied to cognitive performance factors.

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they lack depth and may not be representative of the structure of actual domains to which the ESTATE approach may be applied. Therefore, we elect to integrate ESTATE with an existing Charles River Analytics project with a well defined challenge domain and a need for adaptive training.

During the current reporting period, we have begun integration design and implementation with an ongoing Charles River Analytics effort, Pictorial Representations of Medical Procedures to Train for Effective Recall (PROMPTER). PROMPTER is funded by the U.S. Army Aeromedical Research Laboratory (USAARL) under Government Contract W81XWH-09-C-0049. PROMPTER uses an intuitive, standardized symbology to represent first-aid tasks, a pictorial mnemonic framework to visually represent first-aid procedures, and a microgame-based training method to improve comprehension and recall of the procedures. However, PROMPTER currently lacks significant adaptive training capability; the choice of challenges in the microgame is random or according to a hand-coded estimation of difficulty. Charles River Analytics will use experiments with human participants to evaluate the PROMPTER approach. Therefore, the ESTATE effort may directly benefit from this integration by implementation within the PROMPTER microgame training framework and possibly as a component tested during the human participant experiments. The PROMPTER effort may directly benefit by using the adaptive training technology in ESTATE to improve training outcomes.

1.2.1 PROMPTER Overview

Problem

Historically, the U.S. Armed forces have aggressively sought ways to reduce battlefield fatalities. Advances in evacuation techniques and personal protective equipment are two examples of this approach. However, reducing combat fatalities still demands quick and effective emergency care on the battlefield. The responsibility of providing this care does not fall exclusively on the shoulders of highly trained combat medics. All Soldiers—regardless of their medical background or experience—must be capable of providing immediate, basic first-aid to themselves ("self-aid") or comrades ("buddy-aid") to address a range of critical, but treatable, combat injuries (e.g., hemorrhaging in an extremity). A number of emergency medicine technologies that address these injuries have been recently developed and deployed with the intent of reducing preventable mortality rates. These technologies include new tourniquet designs (Walters et al., 2005) and advanced hemostatic dressings (Pusateri et al., 2003). However, even with such technologies, successful treatment outcomes still require those performing first-aid to rapidly select and effectively execute an appropriate response procedure, all under considerable time pressure in a chaotic battlefield environment. To this end, all Soldiers are required to maintain proficiency for seventeen critical first-aid procedures described in the Soldier's Manual of Common Tasks, Warrior Skills, Level 1 (STP 21-1-SMCT, 2007).

While seventeen may seem a small number of tasks, training Soldiers to rapidly and effectively recall emergency medical procedures in dynamic, highly stressful, and life-threatening battlefield environments remains a challenge. This is due in part to the relative complexity of the procedures themselves, as each first-aid skill is composed of numerous, interrelated subtasks and processes. For example, the single procedure "Perform First-aid for a Bleeding and/or Severed Extremity" (081-831-1032) involves nearly 50 unique steps, divided across three potential wound dressing methods (emergency bandages, chitosan dressings, or field dressings) and two possible tourniquet devices (Combat Application Tourniquets (CAT) or improvised tourniquets). Often, individual subtasks require the Soldier to perform assessments and make rapid decisions that have downstream effects on appropriate treatment (e.g. "Elevate the injured part above the level of the heart, unless a fracture is suspected and has not been splinted"). Successful treatment outcomes require not only the correct performance of individual component tasks (e.g., inserting an intravenous catheter, applying a dressing, administering an injection), but also an awareness of the interdependencies and ordinal relationships between these component tasks as part of the overall procedure. Training Soldiers to become sufficiently aware of these many procedural subtasks and their interrelationships such that they can be immediately recalled under traumatic battlefield conditions will save lives.

Beyond the complexity of the tasks themselves, individual Soldiers vary greatly with respect to their unique skill sets, training needs, and aptitudes. For example, many Soldiers enter the Army with little to no prior experience in emergency medicine and receive less than eighteen hours of first-aid skills training before deployment (Basu, 2005). Others may have experience from serving as Emergency Medical Technicians (EMTs) or in other medical professions. After initial skill acquisition, individual Soldiers' training needs vary greatly, given their unique experiences in the field and the fact that emergency first-aid skills may be called upon very sporadically, if at all, over a particular tour of duty. To maintain sufficient proficiency over long periods of time, Soldiers must continually train and rehearse these emergency response skills and procedures. Unfortunately, the cumbersome information delivery methods of the STP 21-1-SMCT manual (which contains nearly 100 pages of hierarchically ordered, text-based descriptions of tasks and subtasks with no imagery) do not support the efficient review of these complex emergency medical procedures. Also, this manual-based presentation format neither engages the Soldier in the active learning processes of skill rehearsal, nor is it capable of providing the Soldier with useful feedback regarding their current level of preparedness and unique training or rehearsal needs.

Given the challenges of maintaining sufficient first-aid skill competencies and the limitations of existing manual-based training materials, advanced training tools and rehearsal methods are required to enhance and maintain the Soldier's emergency medical skills. These training tools and rehearsal methods must support the depiction of complex procedures through simple, concise representations that may be easily and frequently reviewed by all Soldiers throughout their tour of duty. These representations should be designed for use with training methods that will enhance the Soldier's rapid and effective recall of complex procedures—including all critical subtasks and their interrelationships—under stressful battlefield conditions. Such training methods should not only address individual Soldiers' unique competencies and training needs, but also do so in a way that that effectively engages Soldiers in the training experience. These methods must also motivate the effective retention of procedural first-aid skills over protracted periods of time, which is crucial to reduce the number of preventable combat deaths.

Approach

Training tools and rehearsal methodologies based on visual learning (rather than verbal) of complex, interrelated task structures offer one promising approach to enhance the effectiveness emergency medical skills training and retention. For example, *pictorial mnemonic* training approaches (Estrada et al., 2007), have been demonstrated to support the recall of emergency procedures more effectively than rote memorization of text-based task descriptions. Such methods strive to create a simple visual representation of a task flow that can be remembered by the trainee as a single “chunk” of information. During task execution, this single visual image is recalled and its individual components are “unpacked” to identify critical subtasks, their serial relationships, and dependencies for performing the complex task.

One approach to representing a complex first-aid procedure within a pictorial mnemonic would be to develop a single storyboard depiction of individual subtasks being performed in series, much like the safety cards used by airlines, or procedural first-aid posters found in public buildings. These storyboards typically use a sequence of pictorially realistic illustrations of component behaviors to describe multi-step procedures to users without the need for literacy. However, while such illustrations are appropriate to support rapid procedural *recognition*, they are poorly suited for training rapid procedural *recall*. Their relative complexity makes them difficult to memorize and recall as a single, coherent visual image. In contrast, an effective pictorial mnemonic device must represent a complex procedure through a visual structure that can be recalled as a single image, which can then be unpackaged into its constituent task components. To accomplish this, these mnemonics should leverage a simple, but intuitive symbology to represent critical subtask activities, decision points, and alternative process flows. This symbology must: (1) be appropriate to the emergency medicine domain while remaining highly intuitive to the target audience (e.g., Soldiers with potentially no medical background); and (2) support the effective combination of atomic task symbols into “roadmaps” of complex procedures that can be accurately recalled by the trainee as individual, sufficiently distinguishable visual objects.

However, for improved treatment outcomes, an intuitive visual symbology and pictorial mnemonics for representing emergency medical procedures must also be paired with advanced training methods, both to teach Soldiers how to use the symbology and mnemonics initially (to learn), and over time (to retain). Simply trading static, textual depictions of process flows (e.g. the SMCT manual) with static, visual depictions of process flows (e.g., flash cards) will not support the development of the rich knowledge structures necessary for procedural recall. Similarly, while providing visual training aids may make review of complex training materials more efficient, it will not intrinsically increase the trainee’s motivation to learn first-aid, nor their engagement in the training process.

In contrast, the integration of intuitive, visual training materials with engaging microgame-based delivery methods represents a promising approach for enhancing both the efficiency and the effectiveness of procedural training. Microgames are lightweight, short duration (5-20 minute) computer-delivered games that can support learning over a broad range of platforms (e.g., desktop, laptop, PDA, or cell phone devices). These approaches are low-cost, can be updated quickly and inexpensively to incorporate new training material, and may be easily and cheaply distributed using ubiquitous web-based delivery methods. They are purposefully developed to engage the user, which improves learning transfer (Prensky, 2001) and encourages greater use of the games over time. The brief, visual nature of traditional microgames makes them well-suited to repetitive cognitive skills training, particularly for tasks related to pattern matching, memorization, and visual recall. Microgames also lend themselves to integration with intelligent, adaptive methods to continually assess training performance against pre-determined competency goals and adaptively manipulate the type and complexity of individual microgame tasks to enhance the Soldier's skill acquisition and retention over time.

PROMPTER has previously demonstrated that combining visual task symbologies and microgames is not only feasible, but also that it represents an innovative approach to enhancing the training of medical procedures. The current PROMPTER effort is to develop and evaluate task symbologies and adaptive microgames that use pictorial representations of medical procedures to train for effective recall. The pictorial mnemonics and engaging microgame-based rehearsal methods developed and tested under PROMPTER will allow individual Soldiers to more efficiently develop and maintain the ability to rapidly recall emergency first-aid skills Four major components comprise our approach. First, we are designing an ***intuitive, standardized symbology*** for the individual first-aid task and subtasks that comprise the complex emergency first-aid skills of the Soldier's Manual of Common Tasks, Warrior Skills, Level 1 (STP 21-1-SMCT). This symbology will be designed from a human-centered perspective to be highly usable by its intended audience (ranging from new Soldier recruits with no medical background to trained combat medics), in terms of interpretability, learnability, discriminability, and simplicity. Second, we will incorporate sets of these first-aid symbols within a ***pictorial mnemonic framework*** to visually represent each of the seventeen procedures in STP-21-SMCT. This framework will support the creation of individual pictorial mnemonic devices that effectively convey the related actions of each particular procedure through a single, cohesive and highly memorable visual image. Third, we will design and demonstrate *adaptive,* ***microgame-based training methods*** that leverage these pictorial mnemonic training materials. These microgames will present tasks and challenges relevant to procedural skill acquisition and retention, using engaging game play mechanisms that are continually tailored to individual Soldiers' evolving training needs. The microgame platform and adaptive content-generation process will be both generic and extensible to support pictorial mnemonic-based procedural training across a broad variety of military and civilian application domains (e.g., aviation, process control, natural disaster management). Fourth, we will conduct formal ***evaluations*** to assess the PROMPTER training materials and methods. We plan a set of evaluations to specifically target the usability of the PROMPTER task symbology, pictorial mnemonics, and adaptive, game-based training methods, as well as their effectiveness in supporting Soldiers' learning and maintenance of first-aid skills, in comparison to traditional, text-based training materials.

Implementation

Figure 1, Figure 2, and Figure 3 show examples from the standardized symbology and pictorial mnemonic framework. These symbols and pictorial mnemonics make up the basic elements of the PROMPTER microgames. Figure 4 shows three such microgames that may be constructed with these elements. In the first (a), the trainee must choose the symbol that matches the meaning of the text. In the second (b), the trainee must choose a symbol that does not belong or is out of place in the procedure. In the third (c), the trainee must create a procedure using the individual mnemonics. During a microgame session, the trainees are presented with these individual challenges in quick succession, each lasting no more than seconds.

(a) **(b)**

Figure 1. (a) Illustration of a casualty with an abdominal wound being laid on their back with their knees bent; (b) PROMPTER icon capturing this body position through a simple, intuitive line drawing.

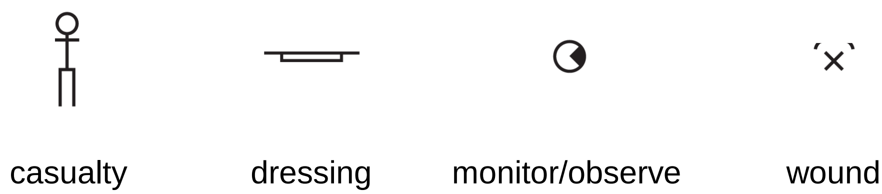

Figure 2. Examples from core set of symbol primitives for commonly occurring objects and actions

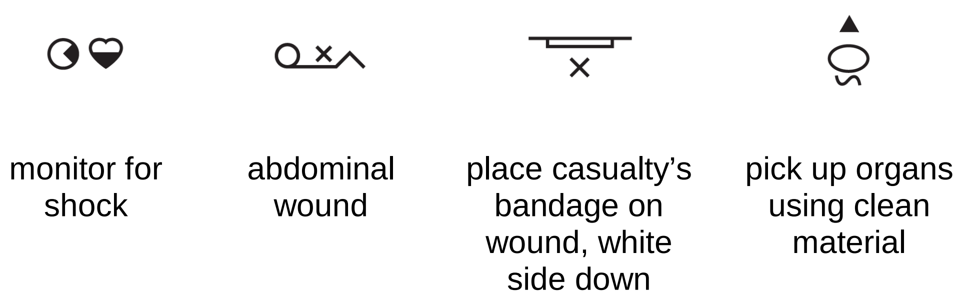

Figure 3. Examples of compound symbols that combine core symbols of the PROMPTER visual alphabet to express more complex task concepts

(a) (b) (c)

Figure 4. Examples of rapid prototypes developed to explore and demonstrate promising mechanics for microgame-based learning of procedural knowledge structures, including games that test and develop: (a) knowledge of the meaning of individual symbols; (b) ability to visually recall overarching task mnemonics; and (c) ability to rapidly reconstruct complex task processes

1.2.2 ESTATE and PROMPTER Integration

ESTATE may use the PROMPTER microgame training platform, existing software, and experiments as a test case for the adaptive training approach. A trainee plays a session of a PROMPTER microgame, and ESTATE creates a skill model of the trainee. The skill model and new challenges are evolved using student-test coevolution until the challenges and evolved skills have reached a significant distance from the initial state (i.e., they have reached the zone of proximal development (ZPD) for the trainee). The set of evolved challenges are packaged into a microgame session for the next time the trainee logs on and attempts the microgame. At this time, the skill model of the trainee is updated and ESTATE again adapts the set of challenges for the next session. Due to ESTATE's avoidance of coevolutionary pathologies, the adaptation drives the trainee towards continuous improvement without cycling, evolutionary forgetting, overspecialization, or disengagement.

Currently, the PROMPTER implementation consists of a server backend and a javascript game client capable of running on multiple devices, including PC web browsers and smartphone platforms such as the Android and iPhone. The game clients receive game content, user profiles, and media from the server via HTTP. The client sends the actions performed by the human user to the server, where they are stored in a database. The user's performance can then be evaluated by a supervisor at a later date. Figure 5 shows a simplified diagram of the PROMPTER architecture. The server also includes a web interface that can be used by supervisors to access user profiles and performance data. For simplicity this interface is not shown in the figure.

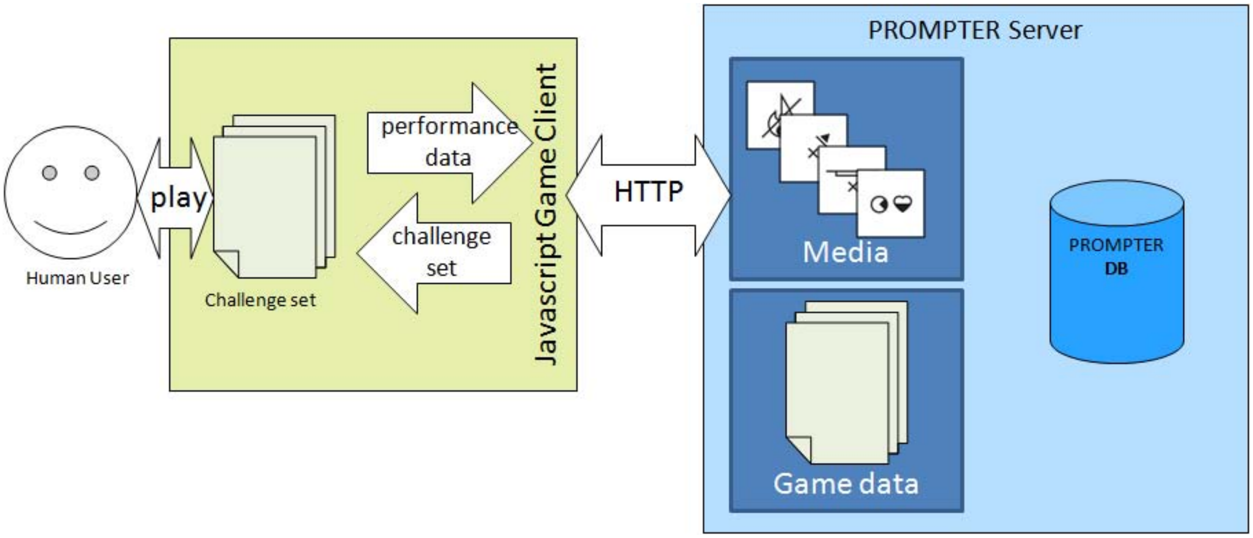

Figure 5. Current PROMPTER Architecture

The client/server model of PROMPTER lends itself towards straightforward integration and modification. To allow ESTATE's simulated players to play PROMPTER's games, modification to PROMPTER code is minimal. Performance metrics, for example, can be accessed programmatically using the server's existing interfaces, which provides trainee performance data in XML format.

To incorporate the ESTATE adaptive training techniques, the PROMPTER game clients will be replaced with a "thin" interface that communicates with the PROMPTER server using the existing messaging architecture. This interface will allow both the simulated trainee as well as the coevolution trainee models to play simulated PROMPTER games.

The PROMPTER server can be re-used with only slight modifications. Currently, PROMPTER clients have no control over which question or challenge is posed when a game is played. The ESTATE adaptive training technique requires complete control over the challenges presented as well as their ordering. This feature may be implemented by expanding the communication protocol between the server and client or by allowing the ESTATE client direct access to the server database (i.e., allowing it to seed the games with the desired challenges). Figure 6 shows the designed integration architecture for ESTATE and PROMPTER pure simulation experiments. The thin interface will lack any visible UI since the players are automated; instead, it serves to connect both the simulated human user and the evolved user models to the PROMPTER server's games and to collect performance data. Figure 7 shows the designed integration architecture for a playable ESTATE and PROMPTER prototype.

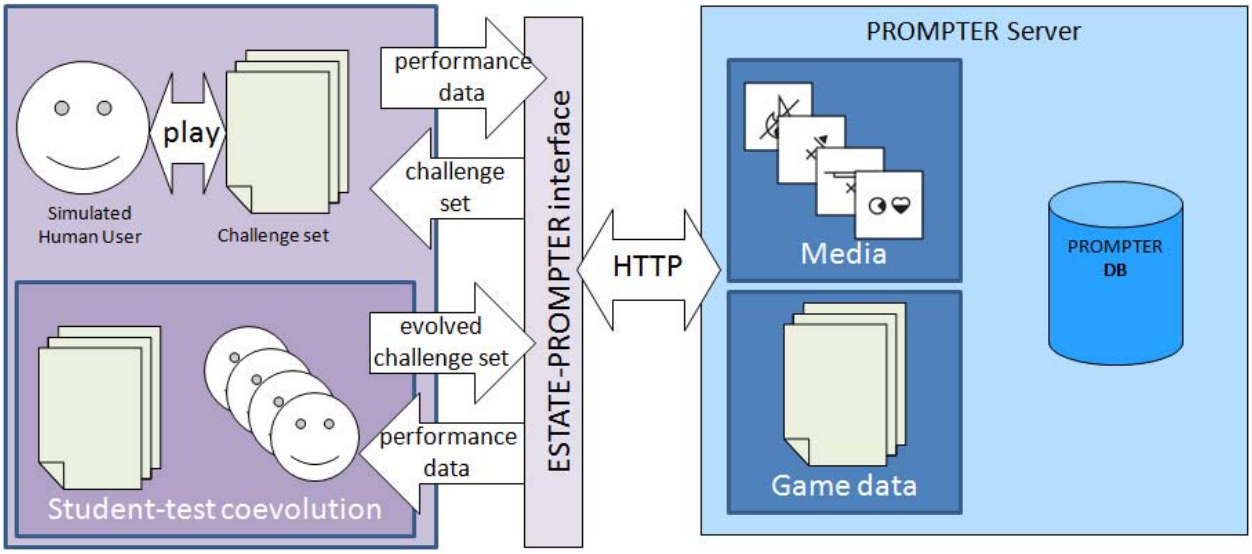

Figure 6. ESTATE-PROMPTER simulation framework integration design

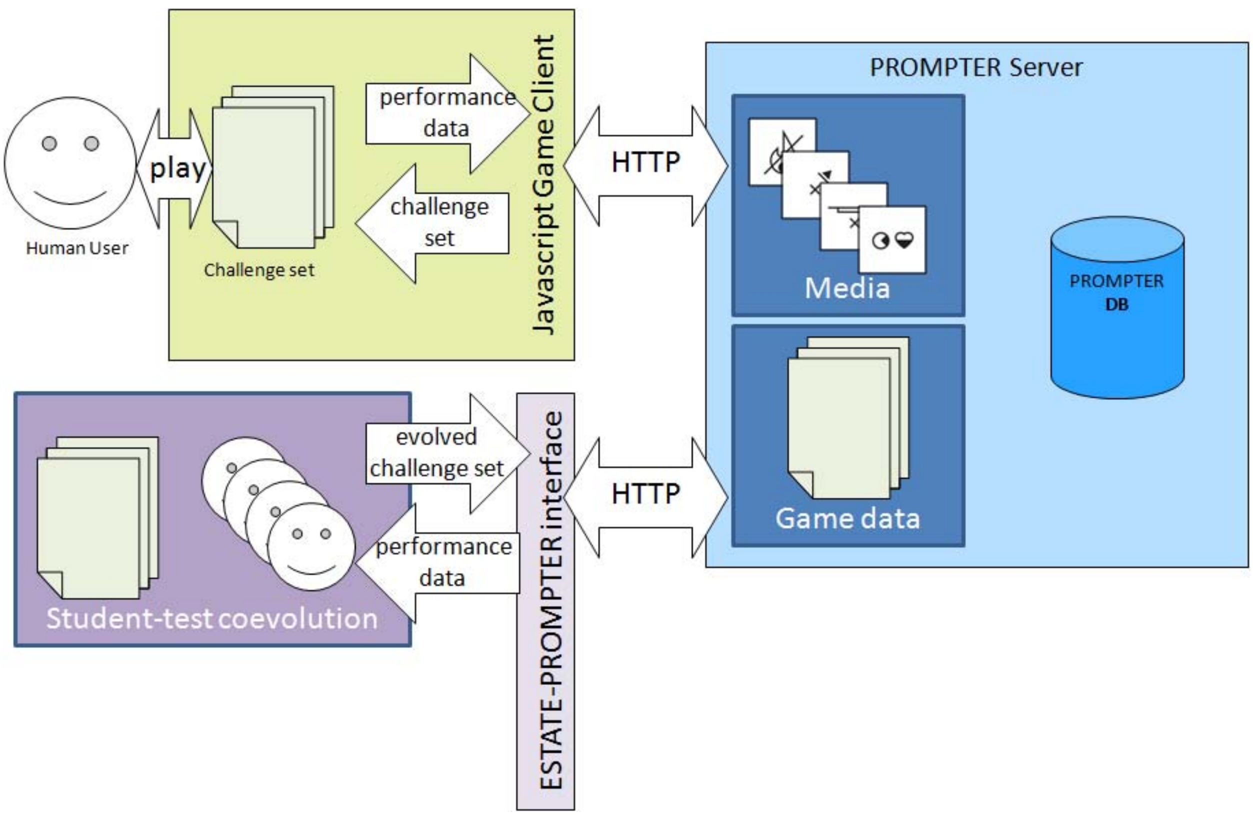

Figure 7. ESTATE-PROMPTER playable integration design

2. Scheduled Items

In the next reporting period we plan to address the following items:

- Continued integration with the PROMPTER microgame training platform
- Development of ESTATE formalisms and simulations for memory-based microgames
- Continued pursuit of development and transition opportunities for the USMC Training Simulations Division

Sincerely,

Brad Rosenberg
Principal Investigator